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# Effects of Different Control Mechanisms Upon Use of a Training Device

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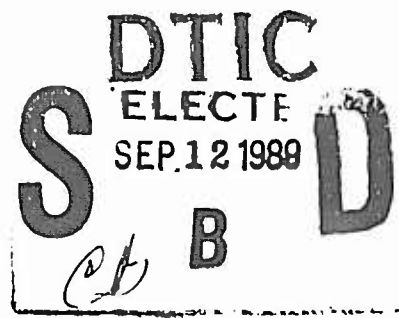
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# EFFECTS OF DIFFERENT CONTROL MECHANISMS UPON USE OF A TRAINING DEVICE

## EXECUTIVE SUMMARY

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### Requirement:

A continuing challenge to the Army is to provide effective training with little or no increase in resources. One training innovation being explored by Fort Knox's Training Technology Field Activity (TTFA) is the Platoon-level Battlefield Simulation (PLBS) training device. Previous research (Graham, 1987) indicated that this training device could help the Army to training command, control, and communication skills. Researchers were concerned, however, about the efficiency of using the system's responding mechanisms for driving vehicles on the PLBS system. This research examined the relative effects of different joystick systems ("Driver" and "Pacman") and different computer response times (2.5 seconds and 1.5 seconds) on soldiers' abilities to drive a vehicle on the PLBS system. The Driver joystick system was designed so that all driving movements were made from the view of a hypothetical Driver inside the vehicle. The Pacman control system design was similar to that of the Pacman game.

### Procedure:

Thirty-four subjects participated in this experiment. These subjects completed two different driving tasks across different routes on the PLBS terrain. One road march went north-to-south (top-to-bottom on the screen) and the other march went south-to-north. The experimental sessions consisted of four trials with two trials for each task. The two trials for the north-south route were always completed first. The subjects used a different type of responding mechanism for each trial. The order of using a particular response mechanism was counterbalanced to control for any possible trial effects.

The responding mechanisms were as follows: (a) a Pacman joystick configuration with a computer response time of 1.5 seconds; (b) a Pacman joystick configuration with a computer response time of 2.5 seconds; (c) a Driver joystick configuration with a computer response time of 1.5 seconds; (d) a Driver joystick configuration with a computer response time of 2.5 seconds. This experiment was thus a 2 X 2 within subject-design with two levels of joystick configuration (Driver versus Pacman) and two levels of computer response time (fast versus slow).

## Findings:

A multivariate analysis of variance (MANOVA) indicated a significant overall main effect for the joystick configuration variable. The subsequent univariate F-tests indicated that the subjects' mean Problem Scores, Off-path Scores, and Time Off-path Scores were significantly lower for the Pacman systems than for the Driver systems. The Pacman joystick configurations led to fewer driving problems and seemed to be easier to use than the Driver joystick configurations. Also, the subjects' verbal reports indicated that Pacman joystick configurations were easier to use than the Driver joystick configurations.

## Utilization of Findings:

Based on these findings, the PLBS was equipped with a Pacman-style joystick configuration. This experiment's findings also demonstrated the importance of the maneuver control system in any combat simulator. This report contains information that will be useful to military and civilian personnel engaged in developing, implementing, and optimizing training simulators similar to PLBS.

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# EFFECTS OF DIFFERENT CONTROL MECHANISMS UPON USE OF A TRAINING DEVICE

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## EFFECTS OF DIFFERENT CONTROL MECHANISMS UPON USE OF A TRAINING DEVICE

### Introduction

A major challenge to the modern Army is to provide more effective training while using fewer resources. This challenge emphasizes the need to more fully exploit available training technologies. To meet this need, the Army Training and Doctrine Command (TRADOC), the United States Army Armor Center (USAARMC), and the Army Research Institute (ARI) have established a joint Training Technology Field Activity (TTFA) at Fort Knox, KY. The mission of this TTFA is to identify, develop, and implement a variety of new technology-based training methods. ARI's mission within TTFA is to conduct research on the methods for using this technology.

One such training innovation developed by Fort Knox's TTFA was a system of computer networked simulators--Simulation in Combined Arms Training (SIMCAT)--to provide training in command, control and communications (C<sup>3</sup>) skills. SIMCAT was created because training C<sup>3</sup> skills in a field environment has become too expensive. The cost of operating and maintaining a tank is estimated to be nearly \$280 per hour (Kristiansen, 1987). Another reason for developing these devices is that the less expensive table exercises and board games have not faithfully reproduced the C<sup>3</sup> problems inherent in combat (Kristiansen).

SIMCAT was thus developed to duplicate as many field exercise C<sup>3</sup> requirements as possible in a low fidelity, low cost, battlefield simulation (Kristiansen, Koger, & Graham). The SIMCAT system involved the networking of seven IBM PC microcomputers. Four of these terminals were used by the SIMCAT students. These terminals were configured to control tank vehicles with one tank per student terminal. A terminal was used by the controller/instructor and another was used by the OPFOR. The seventh terminal was a file server.

At the student terminals, a simulated driver and gunner were used for moving the vehicle and firing at the enemy. Control over the driver/gunner was exercised through a voice recognition system or function pad. Responses from the simulated crew were prerecorded and programmed for appropriate playback. Research conducted by Graham (1987), Kristiansen (1987), and Lampton (in preparation) has demonstrated SIMCAT's effectiveness for training C<sup>3</sup> skills.

However, some problems with SIMCAT were discovered (Kristiansen, 1987). The most pressing problem was that the students experienced some difficulty with controlling the tanks. These difficulties were due to problems with using a voice recognition system for this task. It took the students approximately twenty to thirty minutes to register their voices with the voice recognition system. Additional time was required to train the students to use the voice recognition system in order to control their vehicles. There were also occasions in which the voice recognition system would not recognize a particular driving command because the student's voice changed under the

stress of making an immediate command. These problems with the voice recognition system thus reduced the efficiency of SIMCAT to train soldiers in C<sup>3</sup> skills.

A "touchpad" system was then developed for driving commands. This touchpad system was a direct analog of the voice recognition system. As shown in Figure 1 (taken from O'Brien, 1987), the tank commander gave driving commands by touching a particular spot on the touchpad. However, this touchpad system was also problematic. One problem was that the students were not able to memorize the position of a particular driving command on the touchpad. Hence, they were continually looking at the touchpad while trying to drive the tank. A second problem was that the students had some difficulty in making precise driving movements with the touchpad. A student, for example, might accidentally hit the spot for a hard right turn twice instead of once. The tank would then go in a direction which was not intended by the students. A third problem was that the students frequently made several inputs to the touchpad because of the time delay between making a control input and the system output. With no immediate visual feedback, the students did not realize that their initial input was being processed by the computer system. These problems with the touchpad system reduced the efficiency of SIMCAT to train C<sup>3</sup> skills.

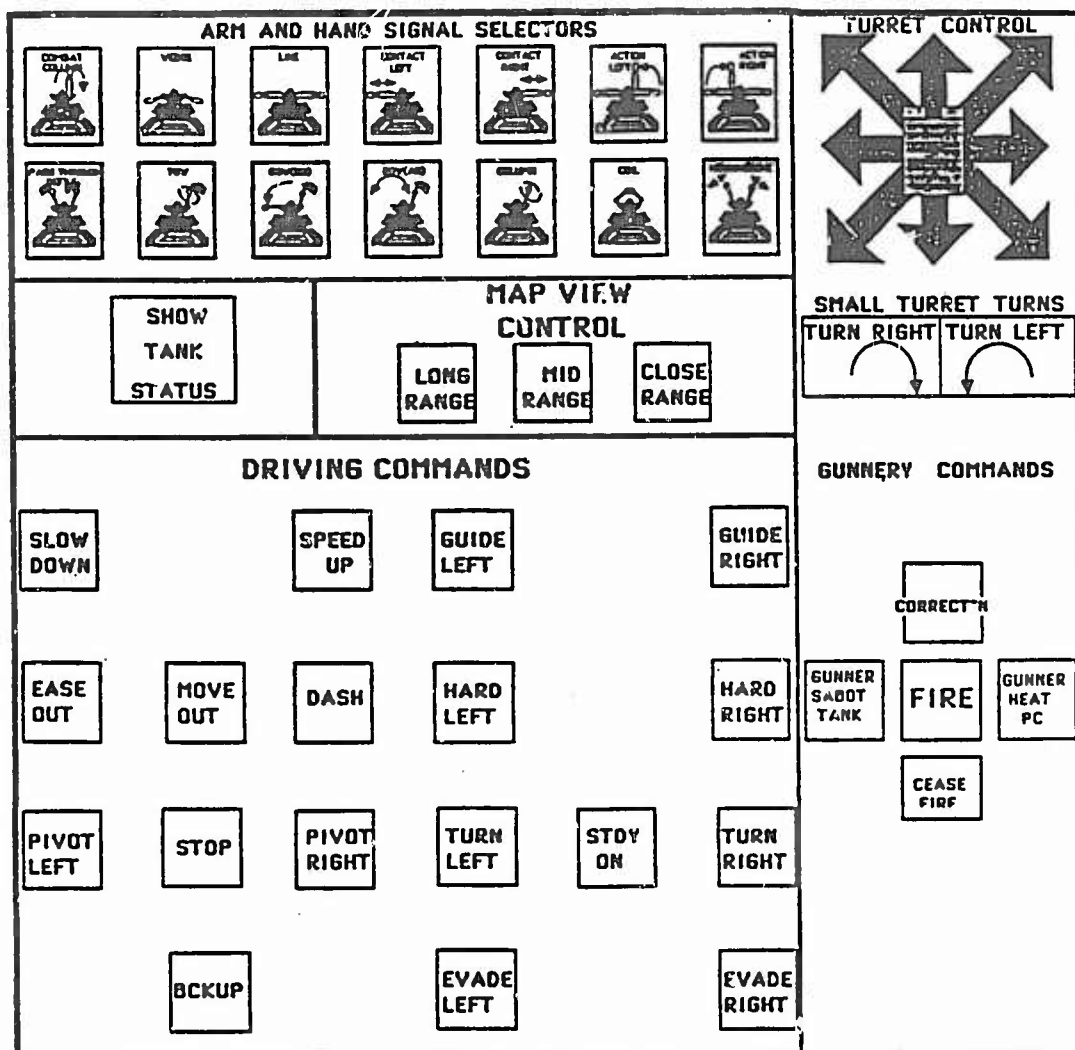


Figure 1. The "Touchpad" system (taken from O'Brien, 1987)

The Platoon-level Battlefield Simulator (PLBS) was then developed to correct shortcomings with the SIMCAT system. The modifications included upgrading the hardware and software system to meet the problems with SIMCAT. A "joystick" responding mechanism was developed to ease the previously mentioned problems with driving a vehicle. The PLBS system used the joystick responding mechanism as a "polling" device. Once during an update cycle the computer checks on the location of the joystick and then inputs the command associated with this location.

The joystick chosen—a Gravis MK VI Joystick Controller—was designed to meet the basic ergonomic standards for this device (see Murrell, 1969; Woodson, 1981). For example, this joystick was the recommended length of 6 inches. This system was also designed so that all driving movements were made vis-a-vis the view of a hypothetical driver inside the vehicle. Hence, this joystick will be referred to as the "Driver" joystick.

The Driver style joystick was a modified two-axis joystick configuration. The vertical (forward-backward) axis was used for starting (forward) and stopping (backward) the vehicle. The horizontal (90 degree left and right) axis was used for making sharp right turns (90 degrees right) and sharp left turns (90 degrees left). Students could also make gradual right and left turns by placing the joystick at either 45 degrees right or left. See Figure 2 (taken from Perceptronics, 1988) for a pictorial description of this system. See the user's manual (Perceptronics, 1988) for a more detailed description of this joystick and PLBS.

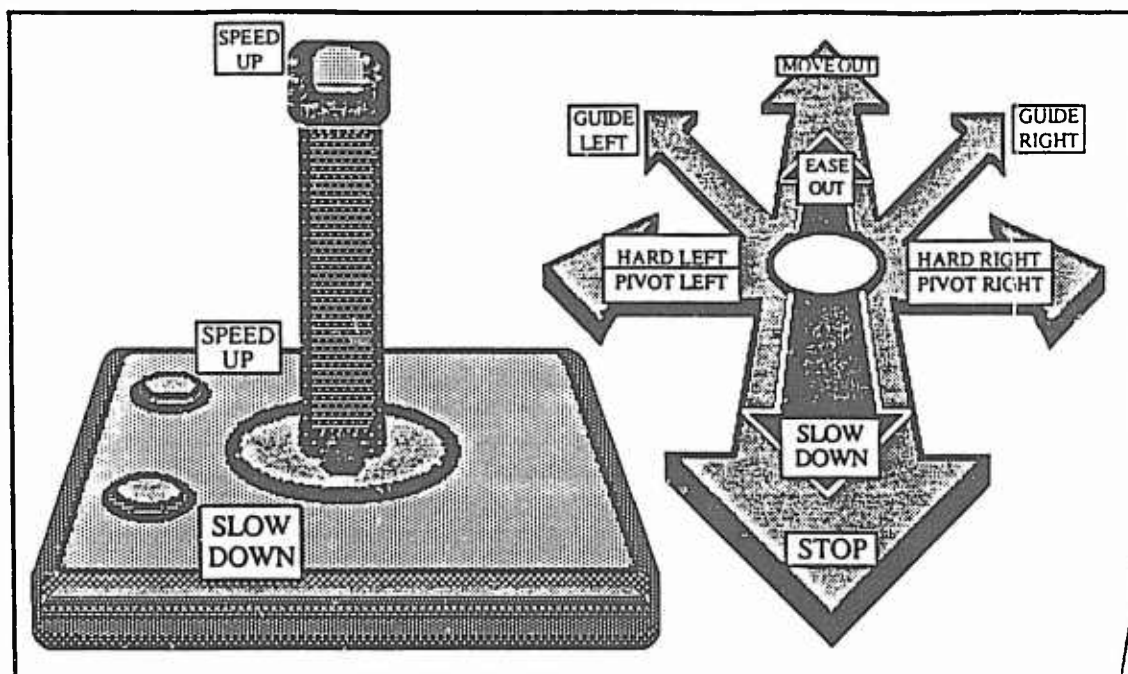


Figure 2. The "Analog" joystick system (taken from Perceptronics, 1988)

The instructions for utilization of the Driver system were as follows: To move the tank out in full speed, move the joystick totally forward. To ease out, move the joystick halfway forward. To continue in the same direction, let go of the joystick. To make a hard right or left turn, move the joystick ninety degrees left or right. To guide the tank 15 degrees left or right, move the joystick 45 degrees left or right. To stop the tank, pull back on the joystick. Use the appropriate red buttons to speed up or slow down the vehicle at increments of 5 KPH. These speed increments were arbitrarily set at 5 KPH by the Fort Knox's operator.

Even though this joystick seemed simple to use, students still had problems with using this system to control their vehicles. Lampton (in preparation) found that tank commanders had difficulty with using the Driver joystick to stay in a platoon formation. This problem made it very difficult for the student platoon leaders to complete their tasks. Also, there was some indication that some students might not be able to control their vehicles vis-a-vis the Driver joystick system because of problems with perceiving the display from the Driver's position. Psychologists (e.g., Witkin, Moore, Goodenough, & Karp, 1967) have found that some people tend to have problems perceiving visual displays from the perspective of another person, e.g., the hypothetical Driver in the tank. These students may then turn the tank to correspond to their perspective rather than to the Driver's perspective.

A new joystick configuration was therefore designed. This joystick was patterned after those used in the Pacman games (See Figure 3). That is, the joystick configuration was a multiple-placement system with the student being able to place the joystick at any location around its circumference. Movements for the assorted tank icons corresponded to the joystick's position as viewed by the student. Also, the students had to continually hold the joystick in the position in which they wanted to drive. This system thus differs from the other joystick system in the following ways:

1. The tank's movements correspond to the joystick's position. A student, for example, moving the tank in a southwest position would hold the joystick in the southwest position.
2. The tank's movements thus correspond to the student's view of the screen.
3. The student must continually hold the joystick in the desired traveling position.
4. The tank stops moving when the student releases the joystick.

Other aspects of this system (e.g., pushing down on the red buttons to speed-up or slow-down the vehicle) were the same as for the Driver system.

The Pacman joystick system was expected to lead to fewer driving problems than the Driver joystick system. This hypothesis, however, was an empirical question. Even though previous research has compared the effects of different two-axis joystick systems upon subjects' performance on a computer task (Mehr & Mehr, 1972), comparisons have not been made between two different types of joysticks.

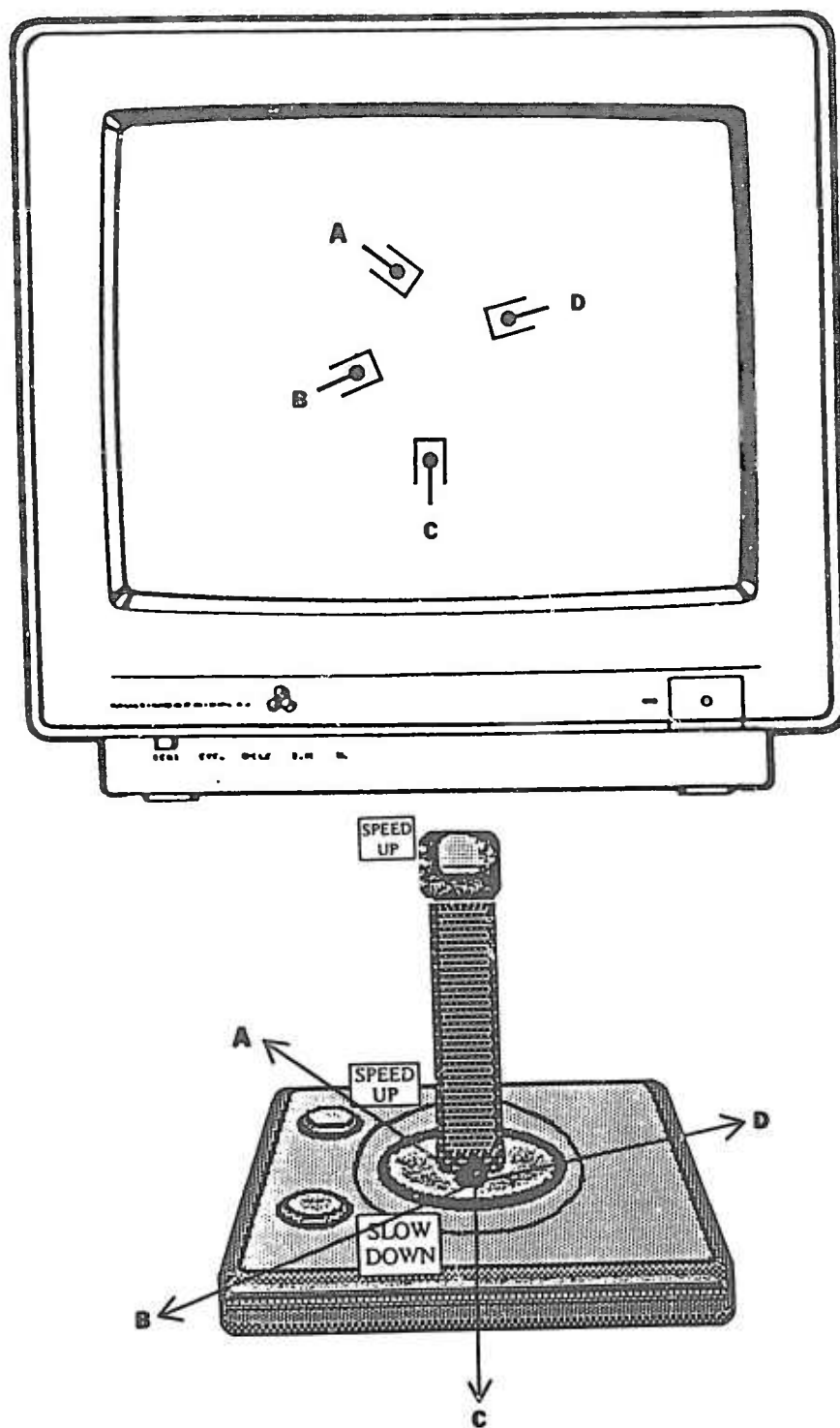


Figure 3. The "Pacman" joystick system.

Another potential problem with using PLBS concerned the system's response time. Because of the networking process involved in the PLBS system, it could take three seconds for the students to see the results of their commands on the screen.

D. M. Kristiansen (personal communication, August 25, 1987) observed that this response delay could lead to driving problems. Furthermore, Norman (1983) has suggested that two seconds delay seems appropriate for any interactive computer system. Norman also noted that the quicker the computer's response time the more satisfied users are with the system. For example, he determined that users are twice as satisfied with a computer response time of one second than with a two seconds response time. It was thought that a quicker response time would make PLBS a more attractive system.

### Purpose

The purpose of this research was to:

1. Examine the relative effects of the Driver and Pacman joystick systems upon students' abilities to control a vehicle on the PLBS system.
2. Examine the relative effects of different computer response times (2.5 seconds and 1.5 seconds) upon students' abilities to drive a vehicle on the PLBS system.
3. Examine the students' preference for different joystick systems and computer response times.

### Method

#### Subjects

The experimental sample consisted of 34 subjects. Thirty-two of these participants were soldiers from the U.S. Army Armor Center at Fort Knox. These subjects ranged in grade from E-6 to O-2 with a nearly equal number of noncommissioned and commissioned officers. Also, the soldiers' military experience ranged from a few months to eighteen years with a median level of four years and a mode of less than a year. A cursory examination of the data did not indicate any effects associated with this variability in the subjects' military experience.

Two subjects were civilians working with the U.S. Army Research Institute at Fort Knox. These two civilians were part of a graduate student training program at the Army Research Institute. These two civilians' data were similar to the other participants.

#### Apparatus

The PLBS training device was used in this experiment. PLBS was modified for this experiment by the development of four different responding mechanisms. As previously indicated, these responding mechanisms were:

1. Pacman joystick configuration with a computer response time of 1.5 seconds (Pacman-fast)
2. Pacman joystick configuration with a computer response time of 2.5 seconds (Pacman-slow)

3. Driver joystick configuration with a computer response time of 1.5 seconds (Driver-fast)

4. Driver joystick configuration with a computer response time of 2.5 seconds (Driver-slow)

### Tasks

The driving tasks consisted of two different road marches across different routes on the PLBS terrain. One march went basically north-to-south (top-to-bottom on the screen) and the other march went basically south-to-north (bottom-to-top). Both routes were of approximately the same length and difficulty, and also required the subjects to make approximately the same number of sharp and gradual right and left turns. The subjects were told to maintain a speed of 30 KPH for both marches. The following scenario was used for both marches:

The tanks for the two subjects (see procedure) had split off from the platoon and needed to reach the platoon by following the route on the map. Each subject was provided with a terrain map of the PLBS database. The subjects were told not to veer from this route. No shortcuts were allowed. When the subjects reached the other tank in their platoon, they were to form a wedge position with their two tanks parallel to each other and slightly behind the lead tank. They were then to move out in conjunction with this other tank until they reached a specified release point.

Practical constraints (e.g., the computer scoring system) prevented the use of a platoon with four tanks. The course of the lead tank in the wedge formation was set by a computer program. This tank was programmed to make a series of sharp and gradual left and right turns. Also, the lead tank's speed was set at 30 KPH.

### Procedure

The experimental sessions consisted of four trials with two trials for each task. The two trials for the north-south route were always completed first. The subjects used a different type of response mechanism for each trial. The order of using a particular response mechanism was counterbalanced to control for any possible trial effects. The counterbalanced order for presenting the different responding systems is presented in Table 1.

Table 1

#### The Order for Presenting the Joystick Configurations

---

Set A (n=8)--Pacman-slow, Driver-slow, Pacman-fast, Driver-fast.

Set B (n=8)--Driver-slow, Pacman-slow, Driver-fast, Pacman-fast.

Set C (n=10)--Pacman-fast, Driver-Fast, Pacman-slow, Driver-slow.

Set D (n=8)--Driver-Fast, Pacman-Fast, Driver-slow, Pacman-slow.

---

Two subjects simultaneously completed a road march. They were instructed to work separately on the different tasks. Minimal oral instructions were also provided on using the different response mechanisms and on completing the different road marches. The subjects were not provided with any practice in using the different response mechanisms before completing a trial. This is standard procedure for this type of experiment (Mehr & Mehr, 1972). Allowing the subjects to practice might have eliminated any possible effects for the different independent variables.

The subjects were also encouraged to "think-aloud" while completing a task. This "think-aloud" process can provide valuable insights into the reasons why subjects are having problems with human-factors design (Lewis, 1985). After completing the four trials, the subjects indicated the response mechanism(s) which they liked best and least. They also were asked to provide a rationale for their choices.

Trained observers also recorded any problems that subjects had with a response mechanism vis-a-vis the following categories:

1. making turns
2. maintaining proper speed
3. maintaining proper formation
4. maneuvering the joystick

These observers also provided written comments about the subjects' problems. And, the observers recorded the amount of time that a subject had to wait for the other subject to reach the wedge position.

#### Training Procedures for the Observers

Three observers were used in this investigation. The following procedure was used to train these observers:

1. A detailed set of instructions was given to each observer.
2. The experimenter discussed these instructions with each observer.
3. Each observer went through a series of mock trials.

The training session was completed when the observers went through a mock trial without making any mistakes. The experimenter emphasized the importance of refraining from helping or interfering with the subjects' performance.

#### Criterion Measures

The main set of criterion measures dealt with the subjects' performance while completing the tasks. This set consisted of the following measures:

1. Time Scores (time in minutes to complete the task).
2. Problem Scores (number of problems recorded by the observers).

3. Off-Path Scores (weighted number of times that the subjects were off the prescribed route).

4. Off-Path Time Scores (weighted time in seconds that the subjects were off the prescribed route).

Time Scores were partially determined by a computer program which recorded the time for both tanks to complete the road march. This time was then subtracted from any time that the subject spent waiting for the other tank to reach the formation. The Off-Path Scores and Off-Path Time Scores were also partially determined by a computer program. The computer program provided a subject's Off-Path and Off-Path Time data vis-a-vis the following categories: (a) 50-60 meters; (b) 61 to 120 meters; (c) 121-180 meters; and (d) more than 181 meters. Because these categories represented different degrees of error, these data were then factored by the following weights for each category: (a) one for the 50-60 meter category; (b) two for the 61-120 meter category; (c) three for the 121-180 meter category; and (d) four for the more than 181 meters category. A subject, for example, who was off-path on three occasions at more than 180 meters received an Off-Path score of 12 (three times four).

The data also included the subjects' preference and think-aloud data. The preference data included the:

1. number of times that a response system was chosen as being the most favorite,
2. number of times that a system was chosen as being the least favorite,
3. comments made by the subjects regarding their choices for the most favorite and least favorite system.

The think-aloud data were the subjects' comments while completing the tasks.

### Design

This experiment was a 2 X 2 within-subjects design. As previously indicated, the factors of this design were two types of joystick configurations (Driver versus Pacman) and two levels of computer response time (fast versus slow). Repetition occurred across both the joystick and computer response time factors.

### Data Analyses

A 2 X 2 MANOVA (multivariate analysis of variance) for repeated measures was computed to analyze the data for the four performance measures. SPSS<sup>X</sup>, subprogram MANOVA (SPSS Inc, 1983), was used to compute this MANOVA. If any overall significant effects were found for the MANOVA test then the appropriate univariate F-tests were computed. The alpha-level for the different analyses was set at .05. The subjects' preference and think-aloud data were analyzed descriptively.

Because two subjects came late to a session, they did not complete their last trial (Driver-fast). The subjects' scores for this trial were the means for their particular order set for that trial. This procedure should have not effected the MANOVA results. Otherwise, the SPSS<sup>X</sup> program would have eliminated these subjects' data for the other performance measures. These subjects' preference data were not included.

## Results and Discussion

The means and standard deviations for the four performance measures per independent variable are presented in Table 2. In Table 3, the means and standard deviations for these measures across the different responding mechanisms are presented.

Table 2

The Means and Standard Deviations for the Four Performance Measures per Independent Variable

	Pacman Joysticks		Driver Joysticks		Fast Response Time		Slow Response Time	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Time in mins	19.74	12.89	20.70	8.68	20.23	10.69	20.33	11.24
Problem Scores*	9.03	7.41	14.62	9.86	11.31	8.98	12.34	9.31
Off-path Scores*	7.66	4.16	9.81	5.41	8.63	4.68	8.69	4.65
Off-path Time Scores*	818	675	1047	831	858	740	1005	785

\*significant difference between the joysticks at the .05 level

The MANOVA analysis indicated a significant overall main effect for the joystick configuration variable (see Table 4). The subsequent univariate F-tests indicated a significant difference between the Driver and Pacman systems for the subjects' Problem Scores, Off-Path Scores, and Off-Path Time Scores (see Table 5).

The subjects' mean scores for the Pacman systems across these three measures were significantly lower than their scores for the Driver systems. This effect occurred regardless of the particular responding mechanism because the interaction in the MANOVA analysis between joystick systems and computer response was not quite significant. The Pacman joystick systems, regardless of their response time, thus led to more efficient driving than did the Driver systems.

Table 3

The Means and Standard Deviations for the Different Performance Measures Across Responding Mechanisms

	Pacman-fast		Pacman-slow		Driver-fast		Driver-slow	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Time in mins	19.60	13.26	19.82	12.70	20.87	7.42	20.78	9.73
Problem Scores	9.47	8.48	8.58	6.27	13.15	9.23	16.09	10.38
Off-path Scores	7.53	4.28	7.79	9.59	9.59	5.06	10.53	5.82
Off-path Time Scores	854	753	781	594	862	737	1231	809

Table 4

Results of the MANOVA Analysis

Effect	Value*	Exact F	Hypoth DF	Error DF	Sig of F
Joystick Configuration	.61	11.90	4	30	.00
Computer Response Time	.11	.95	4	30	.45
Interaction between Variables	.23	2.20	4	30	.09

\*Values based upon the Pillais Test

Correspondingly then, the Pacman joysticks were easier to use than the Driver systems. This point is reinforced by the subjects' think-aloud data. As shown in Table 6, the single most frequent comment made by these subjects concerned problems with manipulating the joystick. And most of their comments about manipulating a joystick were in reference to the Driver systems. Examples of these comments were:

"Seems when I make a guide the machine does a hard turn maybe cause I hold it down too hard." (for the Driver system)

"Turn the wrong way . . . can't do it . . ." (for the Driver system)

Table 5

Results of Univariate F-Tests for the Joystick Configuration Variable with 1 and 33 D. F.

Dependent Variables	Hypoth SS	Error SS	Hypoth MS	Error MS	F	Sig of F
Time Scores	39.46	3547.99	39.46	107.51	.36	.55
Problem Scores	1061.76	2112.23	1061.76	64.01	16.58	.00
Off-path Scores	156.74	239.76	156.74	7.26	21.57	.00
Time Off-path Scores	1781162.47	7730502.47	1781162.47	234257.65	7.60	.01

"I feel frustrated when joystick not responding according to my command." (for the Driver system)

"I don't like holding the controls constantly." (for the Pacman system)

"Where are we going? . . . This is not accelerating. Equipment must have been built by the lowest bidder" (for both systems)

Table 6

Results of the Subjects' Think-aloud Data

Main Problems	Pacman fast	Pacman slow	Driver fast	Driver slow	Totals
Manipulating Joysticks	8	7	11	15	41
Misunderstanding Directions	3	3	1	3	10
Following Route	0	2	4	3	9
Reading Maps	3		0	1	7
Totals	14	15	16	22	67

The observers also noted that the subjects seemed to have problems with manipulating the Driver systems. As one observer noted:

Subject turns the tank all the way around before heading in the right direction. He laughs at mistakes and shakes

his head. He seems to be getting disgusted with it  
(the tank continually moving in the wrong direction).

Several plausible hypotheses can explain the subjects' problems with manipulating the Driver systems. For one thing, the students seemed to have experienced some difficulties in making a response from the Driver's viewpoint. Several subjects complained in their think-aloud data about being disoriented when making a response to the Driver response system. These subjects had trouble, for example, realizing that turning right for the Driver when going down the screen meant placing the joystick to their left. This confusion was also noted in the observational data. Second, the Pacman joystick may have allowed the subjects to make more precise turns. Several subjects noted that the Pacman systems were easier to use because of this reason. Third, the subjects might have been more accustomed to the Pacman-style systems. After all, nearly all of these subjects reported having some previous experience with a Pacman-style joystick.

The subjects might then have been predisposed to use and favor the Pacman configurations. The results of the preference data, however, indicated that this was not the case. As shown in Table 7, the subjects were nearly equally divided in their preference for the Pacman-fast and Driver-fast response mechanisms. Furthermore, their choices for the least liked system were nearly equally divided between the Driver and Pacman joystick systems (see Table 8). The subjects' preference data were not totally congruent with their performance data.

Table 7

Subjects' Choices of Most Favorite Responding Mechanisms by Trials

	Trial 1	Trial 2	Trial 3	Trial 4	Totals
Pacman fast	3	3	0	3	9
Pacman slow	1	3	1	2	7
Driver fast	3	3	4	1	11
Driver slow	1	3	1	2	7
Totals	8	12	6	8	34*

\*Based on 32 subjects with some subjects indicating more than one system.

The issue of maneuverability was clearly the predominant reason cited for either liking or not liking a system. As previously indicated, the main reason for liking the Pacman systems was because they were easier to

use. Conversely, the main reason for not liking the Driver system was that they were hard to control. These findings provide some further support for the notion that the Pacman joysticks were easier to use than the Driver joysticks.

Table 8

Subjects' Choices of Least Favorite Responding Mechanisms by Trials					
	Trial 1	Trial 2	Trial 3	Trial 4	Totals
Pacman fast	5	1	2	1	9
Pacman slow	1	4	1	3	9
Driver fast	3	1	0	1	5
Driver slow	5	3	3	3	14
Totals	14	9	6	8	37*

\*Based on 32 subjects with some subjects indicating more than one system.

There were also other reasons for the subjects' preference data. As indicated, the subjects also tended to like a system because it responded quickly to their commands. This finding supports Norman's (1983) notion that the quicker the computer's response time the more satisfied users are with the system. Some subjects also claimed to like the Driver systems because they were realistic and challenging while the Pacman systems were boring and not very realistic. The subjects' choice for not liking a system also seemed to be associated with which system was used during the first and second trial (see Table 8).

Finally, the results failed to indicate any effect for the computer's response time upon the subjects' performance. Perhaps then, a greater difference in response time than one second is needed to produce a difference in the subjects' performance. Or perhaps, differences in computer response time is not a variable which has an effect upon students' driving performance. S.E. Graham (personal communication, December 8, 1988) has argued for the latter hypothesis because of PLBS' software. The time which varied across the conditions was the time for updating the terminal screen after the computer received a joystick command. However, the time between the screen up-date and the computer's acceptance of a new command remained constant. The subjects thus had the same amount of available reaction time for both (and any) conditions of computer response time.

## Summary and Recommendations

In summary, this experiment's main finding was that the Pacman joystick system led to more efficient driving than did the Driver system. Using the Pacman system may then help make PLBS a more efficient training device. Using this joystick system could enable students to experience fewer problems and frustrations while driving their vehicles. Also, more time could be spent training C<sup>3</sup> skills rather than irrelevant skills, such as responding to the device. Based upon these findings the PLBS training device was equipped with the Pacman joystick system.

This experiment also pointed out the importance of the maneuver control system for any combat simulator. As previously indicated, a good control system would enable military students to spend less time in learning to use the device and consequently they would have more time for training. It is thus recommended that future combat simulators be designed with control mechanisms which are easy for the students to use.

This research has also provided further support for using multiple methods and measures for studying human-computer interactions. The think-aloud method, for example, obtained insights into the reasons for the experimental findings. The convergence of agreement across criterion measures added confidence to the conclusion about an effect for the Pacman system. See DuBois and Smith (in press) for another illustration of using multiple methods and measures to study human-computer interactions.

This experiment also left many questions unresolved. Further research is needed to examine the generalizability of this experiment's findings to other human-computer situations and populations. Further research is also needed to examine the underlying reasons for this experiment's findings. Another experiment is needed, for example, to test the hypothesis that the joystick effect was, partially at least, a function of some students' inability to respond vis-a-vis the Driver's view. This report's experiment should thus be viewed an exploratory investigation on important but neglected issues in human-computer interactions.

The following recommendations can be drawn from this report:

1. PLBS should be equipped with a Pacman style joystick system.
2. Future combat simulators should be designed with control mechanisms which are easy for the students to use.
3. Studies on human-computer interactions should use multiple methods and measures.
4. Further research is needed to examine the generalizability of this experiment's findings to other human-computer situations and populations.
5. Further research is also needed to examine the underlying reasons for this experiment's findings.

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